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AN ABRIDGED COMPENDIUM OF THE EXECUTIVE SUMMARIES OF THE BRIEFING PAPERS PREPARED FOR THE BAY-DELTA OVERSIGHT COUNCIL

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PREFACE

The following is an abridged compendium of the Executive Summaries of the Briefing Papers prepared for the Bay-Delta Oversight Council.

These briefing papers were prepared with the intent of providing the Council with a factual, balanced and comprehensive summary of the current state of knowledge in a specific resource area relevant to the Council's work. The papers were drafted by state agency personnel and subjected to peer review by experts representing diverse interest groups. In addition, reviewers were given the opportunity (not always taken) to submit papers presenting their own views or identifying issues they believe were not characterized adequately in the text of the briefing papers. There "perspective papers" were attached as addenda to the reports and reproduced unedited for the Council's information.

The briefing papers produced for the Council were:

- Delta Water Quality for Drinking Water and Agricultural Uses (August 1993)
- Biological Resources of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Aquatic; September 1993 -- Plants and Wildlife; October 1993)
- Delta Levee and Channel Management (December 1993)
- Status, Trends, and Factors Affecting Sacramento-San Joaquin Delta Water Supplies (March 1994)
- Introduced Species (May 1994)
- Recreation (December 1994)

Two additional briefing papers are currently in process:

- Legal and Illegal Fish Harvest
- Pollution, Pesticides & Toxics.

Although the following provides an outline of the information presented in the briefing papers, it is by no means a substitute for reading the entire series of reports.

WATER QUALITY

[*Draft* Report Published August 1993]

DRINKING WATER QUALITY

The Sacramento-San Joaquin Delta is a major source of drinking water for the majority of California's citizen's. There are, however, serious concerns about the quality of Delta water as drinking water source.

Background:

Drinking water quality in California is maintained through a combination of State and federal regulatory systems. Point and non-point discharge control systems are the primary means of attaining water quality standards.

Two major federal drinking water standards are the Surface Water Treatment Rule (SWTR) and the Disinfectants/Disinfection By-Products Rule (D/DBPR). These two regulations result in a quasi-Catch 22 situation. While the SWTR is designed to assure rigorous disinfection of drinking water, the D/DBPR restricts permissible levels of chemical by-products which are formed as a result of the rigorous disinfection mandated by the SWTR.

Delta waters are enriched in bromide and organic carbon; two constituents that cause problems in water treatment by complicating the attainment of the SWTR and the D/DBPR. Bromide, a salt ion in sea water, enters the Delta through intrusion of saline water from the Bay and ocean. Organic carbon (TOC) (naturally occurring as a result of plant decay processes) comes from a number of sources within and to the Delta. The most significant source of TOC is thought to be drainage from the Delta's peat soil islands, which may contribute up to half of the total TOC in Delta waters.

Disinfection by-products (DBPs) are of particular concern because some of the compounds produced as unwanted by-products of drinking water disinfection may pose a cancer threat.

The lack of an ability to fully protect Delta source waters from contamination raises concerns about treatment reliability and the assurance of public safety.

The Delta's poor water quality increases costs for water purveyors and the public.

Water agencies have identified a number of alternatives for improving the quality of Delta water; prominent among these are options for controlling drainage into the Delta, and alternatives for providing partial or complete isolation of the drinking water supply from the negative water quality influences of the Delta.

PERSPECTIVES ON DRINKING WATER QUALITY

The *California Department of Health Services* notes that the new disinfection by-product (DBP) standards will not only be more stringent, but will also apply to all community water systems of more than 25 customers. Previous regulations applied only to systems with more than 10,000 customers. These smaller retailers typically do not have the technical expertise or financial resources to address the DBP problem adequately. This is especially the case for those drawing water directly from the Delta.

The new DBP standards are expected to be promulgated by the EPA in 1997. Systems with more than 10,000 customers will begin compliance efforts at that time, though planning for facilities to meet those standards needs to begin very soon. Smaller systems, with 25 customers or more, will have until 1999 to achieve compliance.

The *State Water Resources Control Board* believes that the principal issues relating to Delta drinking water quality are sea water intrusion and elevated levels of disinfection by-product precursors in Delta source waters (as described above).

The *U.S. Bureau of Reclamation* suggests consideration of alternative source control measures to better protect water quality in the Delta.

The *California Urban Water Agencies* urge the following goal be included as part of a water quality improvement program: the quality of water provided to urban water suppliers should be such that urban users will have a high degree of assurance that continuous compliance with state and federal drinking water standards will be feasible using proven technologies.

The *Contra Costa Water District* faces significant challenges in using the Delta as a drinking water source. The new regulations will likely require significant capital expenditure and result in substantial increases in annual operating and maintenance expenses.

The *Metropolitan Water District of Southern California* believes it is essential Delta source water protection issues be given a much greater emphasis than they have traditionally received. It too is concerned about the new regulations imposing significant capital costs and higher annual operating expenses.

The *San Francisco Public Utilities Commission* expressed concerns about the dramatic impact Delta water would have on its Hetch Hetchy based system if prolonged water shortages required permanent blending. This system experienced severe direct and indirect impacts when even small amounts of Delta water were introduced into it during the recent drought.

The *Santa Clara Water District* (SCVWD) stated that securing the best source of drinking water is the preferable path to follow. Like other commenters, the SCVWD is concerned about increased financial burdens that will result from the new drinking water standards.

AGRICULTURAL WATER QUALITY

Background:

Approximately 75% of the Delta (520,000 acres) is utilized in agricultural production. All irrigation water for Delta agricultural land is diverted directly from Delta channels. Delta water is also diverted from the southern Delta and conveyed through aqueducts to agricultural users in the San Joaquin Valley and urban users in southern California.

Salinity is the most critical water quality concern shared by agricultural users of Delta source waters. Salinity levels vary greatly within subregions of the Delta. The salinity of applied water has a direct relationship to salt content in the soil solution, which in turn affects crop yields and leaching requirements.

A significant factor in the relationship between water quality and agricultural yield is the differing needs of varying soil types in the Delta.

Soils in the Delta fall generally into two categories; organic and mineral. Western and interior portions of the Delta are mainly organic soil areas, while mineral soils are concentrated in the Southern Delta.

Management strategies and cropping patterns vary depending on soil type. The most important differences in management revolve around irrigation techniques and leaching requirements.

Users in the San Joaquin Valley are similarly concerned with salinity levels in Delta source waters. Under the current drainage system, salts transported by Delta diversions to agricultural users in the San Joaquin Valley are subsequently leached from the soil, collected in drains, transported to the San Joaquin River, and ultimately end up back in the South Delta at higher concentrations.

PERSPECTIVES ON WATER QUALITY FOR AGRICULTURAL USES

The *Department of Water Resources* believes it is reasonable to distinguish between the western Delta and the interior Delta when setting agricultural water quality objectives.

The *State Water Resources Control Board* notes that its previous water quality objectives for agricultural use of Delta water are based upon protection of crops grown in specific areas.

Delta water agencies emphasize they need high quality water for salt sensitive crops grown in their districts. Emphasis on improving water quality in Delta channels and the San Joaquin River needs to be maintained.

AQUATIC RESOURCES

{*Draft* Report Published September 1993}

STATUS AND TRENDS OF ESTUARY AQUATIC RESOURCES

■ GENERAL

Highly dynamic and complex environmental conditions exist in the Estuary, which have historically supported a diverse and productive ecosystem. Throughout the food chain, many aquatic species are in decline, suggesting that the Estuary's ability to maintain aquatic species has decreased. This paper concentrates on discussions of indicator species.

The Estuary's biological resources have undergone a significant transformation over the last century and a half. Many species of non-native aquatic invertebrates and more than 50 species of non-native fish species have been introduced.

■ PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton abundance has declined in the last 20 years in Suisun Bay. Moreover, over the same period, a previously less common species of phytoplankton, which is not a preferred food source for zooplankton, has become dominant. This is an important factor as phytoplankton converts the energy of sunlight into food and is important to the growth or productivity of other organisms as one of the fundamental building blocks of the food chain.

Zooplankton abundance has remained constant throughout the Delta since the early 1970's but the species composition has changed dramatically. Generally, native species have dwindled, while non-natives have increased their numbers.

■ BENTHOS

Benthic organisms (benthos) are animals that live in or on the bottom of the Estuary. With few exceptions, all of the common benthic species found in the Estuary have been introduced.

The introduced Asian clam (Potamocorbula amurensis) has established itself as the dominant species in Suisun Bay. The impact of this filter-feeding organism on phytoplankton is generally believed to be dramatic, though it has yet to be quantified.

- FISH

White Catfish: Abundance has declined severely since the mid-1970s.

Delta Smelt: Unique to the Estuary. The U.S. Fish and Wildlife Service added the Delta smelt to the Threatened and Endangered Species list in March of 1993.

Longfin Smelt: Fluctuations in abundance are closely correlated to freshwater flows between February and May. No such similar relationship exists for Delta smelt. There are petitions presently pending to place the longfin smelt on the federal endangered species list. [As of this writing, the U.S. Fish and Wildlife Service had determined that the longfin did not merit listing.]

Sacramento Splittail: Endemic to the Estuary. Spawning and nursery habitat have been significantly reduced through land reclamation. A petition for listing under the federal Endangered Species Act has been submitted to the USFWS.

Sturgeon: White sturgeon and green sturgeon are both anadromous and native to the Estuary, though the latter is much less common.

Pacific Herring: Pacific herring support a large fishery in the San Francisco Bay. Its population has been relatively stable.

Starry Flounder: Native to the Estuary. Overall abundance has been low since 1986.

Caridean Shrimp: There are five relatively abundant species of shrimp in the Bay; four are native and one was introduced from the Orient. Each species utilizes the Bay as nursery area to a varying degree.

Striped Bass: Striped bass were introduced as a sport and commercial fish in the late 1800's. Population levels have declined substantially since the 1960's. 1990 estimates were at a record low .

Chinook Salmon: There are four distinct salmon runs in the Estuary system; named for the season of their upstream migration. They are the spring, fall, late fall, and winter. Today, fall run are the principal run found in the Sacramento and the only run found in the San Joaquin drainage. About 80% of all four runs are produced in the Sacramento basin. Typically, over 90% of all Central Valley spawners are fall run fish. Central Valley chinook typically remain in the ocean from two to four years before they begin their return to freshwater to spawn and die.

Natural salmon populations have been augmented by hatchery production. Release of hatchery fish in the lower Estuary instead of releasing them at the hatchery has increased survival and maintained a relatively stable ocean fishery since the 1950's, though with a relatively reduced level of natural stocks.

Sacramento River Basin: Fall-run chinook salmon returning to the Sacramento River basin in 1991 was estimated to be 116,900, about the same as 1990 but 36% below the 10-year average of 171,500. 1992 DFG estimates of the late fall-run present in the upper Sacramento River was 10,400. 1992 DFG estimates of the spring-run in the Sacramento River above Red Bluff was fewer than 500. In the late 1960's, the spring-run numbered in the 20,000s. 1992 DFG estimates of the winter-run in the Sacramento was 1,200, down substantially from the 118,000 estimated in 1969, but up from 1991's low of 200. DFG expects low return numbers for the next several years. The winter-run is listed under both the state and federal endangered species acts.

San Joaquin Basin: Salmon populations in the San Joaquin have fluctuated widely since the early 1950's when counts were begun. 1991 counts of fall-run chinook salmon produced an estimate of 1,100, well below the 76,100 that returned in 1985. Traditional indices of salmon populations suggest that most runs of chinook salmon in the Estuary and its watershed have declined significantly in recent years, with little evidence suggesting near-term improvement.

FACTORS AFFECTING THE AQUATIC RESOURCES OF THE ESTUARY

■ THE INFLUENCE OF DELTA INFLOW ON AQUATIC RESOURCES

Freshwater flows into the Delta affect biological resources both in the rivers above the Estuary and in the Estuary proper.

A USFWS model identified water temperature and diversion, rather than flow, as the controlling factors for success of outmigrating salmon. It is important to note that needs of the various salmon runs may differ. A strong statistical correlation exists between spring flows of the Tuolumne and Stanislaus rivers and returning runs of adult salmon to those rivers 2 1/2 years later. USFWS, NMFS and DFG advocate minimum spring flows in the San Joaquin River to improve salmon survival in the Delta.

Seaward fall migration abundance of American shad reacts directly to high flow in the previous spring.

White sturgeon populations are highest following high Sacramento River flows in the late winter and spring.

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■ IMPACTS OF DIVERSIONS FROM THE SACRAMENTO RIVER

The principal evidence on effects of diversions relates to salmon outmigrants. Mortality of outmigrating salmon entering the Delta through the Cross Channel and Georgiana Slough is estimated to be twice that of smolts remaining in the Sacramento's main stem. This is also likely true for other fish.

The impacts of flow splits at Three Mile Slough on salmon outmigrants have not been evaluated. Studies do suggest Three Mile Slough is a major transport route for ocean salts into the interior Delta. If these studies are confirmed, it is also likely a conduit for fish, eggs and larvae from the Sacramento River to the interior Delta, where fish, eggs and larvae have lower survival rates.

■ THE INFLUENCE OF REVERSE FLOWS

Reverse flows, which occur when total upstream flow exceeds downstream flow as a partial consequence of the influence exerted by operation of the project pumps, tend to move fish and their food supply toward the pumps rather than toward the ocean.

Flow reversals may impede migration and increase mortality of salmon smolts.

■ LOSSES FROM WATER PROJECT DIVERSIONS

Intakes at the State and federal pumping plants are screened.

Entrained fish are trucked to the western Delta for release. However, a small to large proportion of these fish die as a result of associated stress and predation at the point of release.

Predation, particular of salmon by striped bass, in Clifton Court Forebay is of significant concern.

Two major disadvantages of having large water diversions from the south Delta are:

- ❖ No flow can bypass the intake, so all fish must be captured and transported to another location for release, suffering associated stress mortality; and,

- ❖ Since water is being withdrawn from a large "pool" [the Clifton Court Forebay] which is a major nursery for some fish and a permanent residence for others. the capacity of the "pool" to support these populations is diminished through effects on the fish and their food supply as a consequence of project operations.

Experience has indicated that temporarily curtailing or halting diversions within the present configuration of the Delta does little to protect resident fish species.

■ TEMPERATURE IMPACTS

Water temperature has a strong influence on the lives of all fish and their food supply. The principal identified temperature requirement in the Estuary is for cool temperature to maintain salmon survival in the spring. Analyses indicate water temperature in the Delta is generally not influenced by manipulating reservoir releases. The Delta is so far from reservoirs that water and air temperatures have generally reached equilibrium.

■ THE INFLUENCES OF DELTA OUTFLOW

Outflow and Salinity: Magnitude of Delta outflow regulates salt water intrusion into Estuary. A common opinion held by many biologists who are familiar with the estuary is that biological phenomena of primary interest are driven by flow rather than salinity, with the exception of striped bass spawning which is clearly driven by salinity.

Physics of Outflow: The entrapment zone (an accumulation of suspended particles) occurs near the location of the upper end of the salinity gradient and is an important fishery nursery area. Production tends to increase when outflows are maintained at a moderate level.

Bay Fishes and Invertebrates: The magnitude of Delta outflow strongly influences the *distribution* of almost all estuarine fishes and invertebrates, but the relationship of flows to *abundance* for most species is not as well documented. Still, for several species, there is a strong positive relationship between outflows and abundance.

Striped Bass: Survival of young striped bass increases in proportion to Delta outflow during April through July.

Chinook Salmon: Salmon smolts migrate through the lower Estuary faster than net flow would transport them, thus their survival is apparently not related to outflows.

■ INFLUENCES OF SALINITY

The only fishery regulatory standard which reflects a need clearly dependent on salinity is striped bass spawning in the San Joaquin River.

■ INFLUENCES OF INTRODUCED SPECIES

The shift from native to introduced fish is much greater in the freshwater portion of the Estuary than in the salt and brackish water portions. The ecological significance of the changes wrought by introduced species is uncertain. With regard to abundance of various fish species, declines in abundance have not coincided with increases in introduced species sufficiently for the introduced species to be the likely cause of observed declines.

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- INFLUENCES OF FOOD LIMITATIONS

Many biologists suspect that food limitations may have played a role in recent declines in fish populations. The abundance of a number of components in the food chain has decreased over the last twenty years.

- IMPACTS OF TOXICITY

A key unanswered question is whether continuing point and non-point discharges have toxic effects on aquatic resources.

- THE INFLUENCES OF LEGAL HARVEST

The issue is whether harvests are sufficient to inhibit populations' ability to maintain themselves or to be responsible for observed changes in abundance. To date, there has been no evidence correlating declines to harvests.

- THE INFLUENCES OF ILLEGAL HARVEST

DFG believes illegal salmon take in the Estuary and in the ocean has no significant impact on the resources, including harvests by foreign fisheries.

- IMPACTS OF LAND RECLAMATION

Historical land reclamation destroyed most of the tidal marshes in the Estuary and seasonally flooded wetland upstream from the Estuary and probably caused the extinction of some species and the decline of the Sacramento splittail.

- IN-DELTA DIVERSIONS

Diversions onto Delta agricultural lands are made through many small unscreened intakes. These diversions can add up to approximately the same magnitude as the amount of water diverted into the Tracy Pumping Plant . Evaluation of fish losses and potential screening methods is underway.

CONCLUSION

Dealing with the effects of water development should be the cornerstone of any restoration plan. This involves providing adequate flows or salinities for various fishery needs, providing better fish screens and making some structural changes in the water distribution system to deal with adverse effects associated with the nature and location of the major water diversions.

WILDLIFE AND PLANT RESOURCES

{*Draft* Report Published October 1993}

STATUS AND TRENDS

■ GENERAL

A diverse assemblage of wildlife and plant species inhabit the Estuary's channels, smaller rivers, creeks, and wetlands. For several species groups, such as wintering and nesting waterfowl, the Estuary provides essential habitat. A number of species unique to the Estuary have experienced declining trends in their numbers and distribution, some of these are threatened with extinction.

■ WILDLIFE HABITATS AND PLANT COMMUNITIES

Historically the Estuary, a region where salt and freshwater mix, supported a vast complex of tidal salt, brackish and freshwater marshes and riparian woodlands. The wetlands within this historical range of tidal marshes were influenced by varying saline conditions throughout the year. Today, only remnants of the historic marshes exist.

Mudflats and salt ponds are the predominant wetland types found in the San Francisco Bay region today. San Pablo Bay has an abundance of intertidal mudflats and farmed wetlands, and the Suisun Bay/Marsh is primarily comprised of diked brackish marshes. Most farmed wetlands occur in the Delta and North Bay. The largest diked seasonal wetland in the Estuary is the Suisun Marsh. The following is a brief description of some of the most important community types found in the Estuary.

Tidal Marshes: Tidal marshes are areas that are exposed to the daily tidal cycles and vary in the amount and influence of the salt water tides versus the freshwater influences of rivers and creeks. At least 82% of the region's tidal and salt marshes have been filled or converted to other wetland types. Tidal marshes currently comprise 44,370 acres of the Estuary's wetlands.

Freshwater Marshes: Freshwater marshes include areas that are both seasonally and permanently flooded by primarily fresh water. Freshwater marsh, which comprises less than one percent of the Bay's area, can primarily be found in the western and southern Delta, representing only a fraction of historical acreage.

Intertidal Mudflats: Mudflats are living systems of diatoms and other microalgae, protozoans and a multitude of arthropods, annelid worms, and mollusks. Exposed mudflats are exploited as a food source by millions of shorebirds, which are probably the most prominent wildlife group

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associated with this community type. Wintering shorebirds of the Pacific Flyway use these mudflats for feeding habitat, migratory staging areas and refugia.

Vernal Pools: Vernal pools are seasonal pools of water that fill with rainwater during the winter and evaporate by the end of spring. They provide highly specialized habitat of great botanical significance. More than 200 plant species are found in vernal pool communities, and over ninety percent of them are considered California natives. As compared to other wetland types, vernal pools contain the greatest number of special status plant species.

Diked Wetlands: Diked wetlands are former tidal areas which, through the use of dikes, are partially or totally excluded from tidal action. The Suisun Marsh is the largest diked wetland in the Estuary, supporting a large portion of Central California's waterfowl population and is especially important in dry years.

Farmed Wetlands: Farmed wetlands are agricultural lands which still retain values for wildlife habitat. Farmed wetlands are the Estuary's most abundant wetland type, important feeding areas for wintering waterfowl, and important substitute habitat.

Riparian Woodland: Riparian woodlands are generally restricted to the banks of streams and channels. An estimated 768,000 to 960,000 acres of riparian woodland was believed to have existed in the Estuary before reclamation occurred. Presently, riparian woodland covers only 12,513 acres of wetland habitat in the Estuary. Riparian woodland habitat is the rarest wetland habitat in the Estuary. It is critical habitat for wildlife supporting a large and diverse group of species. Riparian habitats provide a multitude of benefits including nesting and cover, water temperature control through shading, aquatic habitat for fish and insect species, and a source of carbon through leaf and insect drop.

Uplands: Historically, uplands immediately adjacent to the tidal marshes of the Bays probably consisted of perennial bunchgrass prairies, coastal scrub, and valley oak woodland/savannah. In the Delta, at about the 100 year flood line, riparian forest graded into valley oak savannah and broad reaches of perennial grasslands interspersed with vernal pools. The losses of these native habitats, especially adjacent to wetland communities, has had a severe effect on many wildlife species leading many to become special status species. Currently, broad-leaved evergreen forest is the most common native upland community. The most common non-native upland community is urban landscaping.

■ SPECIES STATUS AND TRENDS

Birds: Historically, the Estuary has been a wintering and migratory haven for tens of millions of shorebirds and waterfowl. Today, the Estuary plays a critical, synergistic role along with Sacramento Valley ricelands and waterfowl areas, and the grasslands in the northern San Joaquin Valley to continue to support nearly two-thirds of the Pacific Flyway's wintering waterfowl.

Flooded croplands in the Delta provide the largest acreages of "wetland" available to waterfowl in winter. The San Francisco-San Pablo Bay system is recognized as a site of hemispheric importance to shorebirds. Several special status bird species inhabit the Estuary.

Mammals: Historical accounts of wildlife attest to large and diverse populations of mammals. Once abundant mammalian fauna is now dominated by species which are more adept at tolerating human populations. The red fox, an introduced species, has expanded its population considerably to the detriment of native species. Several mammal species are currently species of special concern due to loss of habitat and habitat alteration or degradation.

Amphibians: Amphibians of the Estuary are generally found in marsh or riparian habitats, although a few also reside in upland areas. Introduced species such as the bullfrog, are now abundant and widely disruptive to many amphibian species in the Estuary. The California Tiger Salamander, Foothill Yellow-legged Frog and the California Red-legged Frog are species of special concern.

Reptiles: Most reptiles of the Estuary are restricted to upland or agricultural habitats. The only aquatic reptiles are the western garter snake, the giant garter snake, and the western pond turtle which are believed to be declining.

Invertebrates: Little is known about the overall status of invertebrate species than other animal groups.

Plants: Botanists recognize that the diversity and vigor of the Estuary's plant species are indicators of the health of the Estuary's entire ecosystem. The large number of listed and candidate plant species indicates a declining trend. Nineteen special status plant species are associated with habitats in the Estuary region.

FACTORS AFFECTING WILDLIFE AND PLANT RESOURCES

- HABITAT ALTERATION AND DEGRADATION

Drastic alterations to the natural Bay-Delta system occurred during the last century as a result of hydraulic mining and land reclamation activities. Habitat loss and alteration continue today. Habitats are being fragmented into areas that are only remnants of the original ecosystem. Concentrating wildlife into smaller, isolated areas makes them more vulnerable to disease and predation. Loss of habitat has affected all groups of wildlife and plant species.

■ AGRICULTURAL PRACTICES

Agriculture is both detrimental to and of positive value to native wildlife species. Agricultural development has caused a decline in native wetland habitats available to wildlife, including vernal pools which are critical habitats for a number of narrowly distributed plant and invertebrate species. Yet agricultural lands continue to provide important feeding and resting habitat for the Pacific Flyway waterfowl and shorebird populations.

■ FLOOD CONTROL AND LEVEE PROJECTS

A combination of upstream diversion and reservoir storage of stream flows has reduced the transport of sediments and nutrients that feed downstream wetland habitats and natural floodplains. The practice of rip-rapping waterside leveee slopes reduces aquatic and riparian habitats, adversely affecting the species dependent on these habitats. However, maintaining existing wildlife habitats within the islands depends on the existence of the levee system because many islands are below sea level. Breaching the levees would cause the total loss of these island wildlife habitat areas and instead convert them to open water areas of little value to wildlife.

■ WATER OPERATIONS AND WATER QUALITY

Water development and water supply operations in the Delta affect salinity distributions within the Estuary, which, in turn, alters the distribution of wetland habitat. This benefits some species and is detrimental to other species.

■ POLLUTANTS

Contaminant exposure impacts can result in slight changes in nesting behavior to complete reproductive failure.

■ HUNTING

Intensive, uncontrolled hunting can adversely affect the number and distribution of wildlife populations. However, limited hunting can provide a net beneficial effect in areas which are managed for hunting. Managed duck clubs provide valuable food and cover plants, as well as nesting and breeding habitat for waterfowl and other wildlife.

■ OTHER FACTORS

Several other factors contribute to the current status of wildlife and plant resources in the Estuary. Recreational development and boat traffic cause loss of habitat, shoreline erosion, and disturbance to wildlife species. Introduction of species such as the bullfrog and red fox, as well as numerous plant species, cause direct losses through predation or indirect losses through competition for limited space and resources. Domestic animals impact native species through direct predation and loss of habitat by grazing.

CONCLUSION

The quantity and quality of available habitat is one of the most important factors limiting wildlife and plant populations. The preservation of remaining riparian habitat and wetlands, and ultimately increasing their acreage, is the most important and effective action needed to reverse the overall declines in the Estuary's populations of plant and animal species.

LEVEE AND CHANNEL MANAGEMENT

{*Draft* Report Published December 1993}

INTRODUCTION

Without levees, the Delta, as we know it would not exist. Delta levees serve many functions, from serving as wildlife habitat and protecting wildlife habitat on the islands, to playing an important role in maintaining Delta water quality and, of course, providing flood protection. Levees, and the channels maintained by them, are also critical to the Delta's role as the hub of the state's water transfer system.

Reclamation of the Delta began in the 1800s. Since that time, the height of Delta levees, relative to land side elevations, has increased from about five to twenty-five feet, generally because of subsidence of the islands. Many of the Delta's levees were built in a piecemeal fashion over several decades. In most cases, they were engineered without the benefit of modern scientific knowledge of geology, hydrology, geophysics or subsidence (the lowering of peat island interior land levels as a result of soil erosion and microbial decomposition accelerated by agricultural activity). Consequently, there has been and continues to be uncertainty about their ability to continue to protect Delta resources.

The Delta Flood Protection Act of 1988 (SB-34) sought to provide a focus for coordinated engineering investigations and improvement projects for non-project levees, with regard to overall design, maintenance, and protection of environmental values. Controversy over implementation and management of SB-34 programs meant to supplement local projects to improve levee conditions has stymied efforts to move forward as expeditiously as many would like.

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■ HISTORY OF DELTA LEVEES

In 1893, the Corps was given federal jurisdiction over flood control. Today, the Corps manages a comprehensive program, the Sacramento River Flood Control Project (SRFCP), which focuses on levee improvement and maintenance.

The Corps is responsible for "project levees" constructed as part of the SRFCP, located mostly along the Sacramento and San Joaquin rivers and maintained to relatively high Corps standards. Nonproject levees (which comprise about 75% of all Delta levees) were constructed piecemeal by land owners and local reclamation districts and are maintained to varying degrees, although generally to a lower standard than those maintained by the Corps.

Flooding in each year from 1980 through 1983 and again in 1986 illustrated the vulnerability of nonproject levees and caused an estimated $100 million in damage to the levee system, of which $65 million was paid for by the Federal Emergency Management Agency (FEMA). As a condition of future disaster relief, FEMA has imposed a minimum standard requirement for improvement of nonproject levees. As of November 1991, while most districts have made some progress toward satisfying the HMP, only four of forty-seven inspected districts complied with the minimum criteria.

■ BENEFITS DELTA LEVEES PROTECT

Levees not only provide direct flood control protection for Delta lands and highways, railroads, natural gas fields, utilities, major aqueducts, homes and marinas, but they also provide indirect benefits to wildlife, Delta agriculture, water quality and recreation.

■ DELTA LEVEE FAILURE MECHANISMS

Levee failures can be categorized principally by the major type of failure (stability, overtopping, seepage/erosion) and then by contributing factors (cracks/fractures, encroachments, deformation, sink holes, burrows, poor foundations). Subsidence, of the island interior and the levee itself, is another factor that must always be addressed when seeking to maintain levee stability. Seismic activity is also considered to be a probable failure mechanism. However, there is still only minimal understanding of how seismic events actually affect levee stability and what the impacts of a major quake would be.

Subsidence: Subsidence, or lowering of the land surface, results primarily form peat soil being converted into gas. Controlling subsidence should be a significant element of any Delta flood control plan.

Stability: Factors affecting stability include size, shape, composition of foundation materials, strength, deformability and water pressure.

Overtopping: Overtopping failure occurs when the crest of a levee is lower than the water level. Overtopping can occur not only as a result of the presence of flood flows, but also as a consequence of high tides and wind. Overtopping is of particular concern in the north and west Delta.

Subsurface Seepage Erosion: Water seeping through or beneath levees contributes to erosion problems and a levee subject to such seepage may wash away from the inside out as a consequence of the formation of "pipes" (large holes).

Seismic Activity: Preliminary studies have been inconclusive about the capabilities of organic soils beneath the levees to either amplify or reduce ground motions triggered by earthquakes. Concerns remain, however, that they would be susceptible to liquefaction (a condition that can occur during earthquakes when soil loses most of its strength to hold together and behaves essentially as a viscous liquid) and damage during moderate to strong earthquake shaking.

- FAILURE MODES

Cracks and Fractures: While cracks do pose a stability problem, they pose a greater danger by providing shorter, unobstructed pathways for piping to occur.

Encroachments: Encroachment of structures onto levee slopes may reduce the level of protection provided by the levee system and also make levee inspection, maintenance and improvements more difficult.

Erosion: Levee waterside slopes are subject to varying erosional effects from channel flows, tidal action (which can cause water levels in some channels to vary by as much as 4 feet daily), wind-generated waves, and boat wakes. Although vegetation can contribute to piping problems, it is generally desirable as a tool in controlling erosion. However, continual wave action at normal water levels frequently undercuts vegetation at the waterline, and can lead to progressive caving and erosion of the levee slope.

Deformation: Levee foundations composed of peat or other soft organic soils are analogous to toothpaste and are similarly squishable..

Seepage: Because interior land levels in many areas are so far below channel water levels outside the levees, seepage is a continual problem that contributes to instability in the low lying islands of the central and western Delta.

Sinkholes: Sinkholes are depressions in the land side of the levee that are typically wet or filled with water.

Rodent Burrows: Rodent burrows increase the potential for piping problems to develop.

LEVEE DESIGN

Levee conditions in the Delta are unique. Delta levees protect lands which are far below the water level. Consequently, while levees in other regions generally need to be able to sustain pressures on an intermittent basis, Delta levees are really earthen dams which must function as continuous water barriers. Thus, Delta levees must remain fully functional during any improvements or repairs.

There are six main components of levee design: levee material, levee height, slope and foundation stability, seepage control, deformation control and erosion control.

LEVEE FUNDING

The cost of rehabilitating or raising the level of protection of a levee ranges from $1.5 million to $4 million a mile, depending upon the condition of the levee and its location. Because local landowners and reclamation districts cannot raise sufficient funds themselves, and SB-34 monies are also not of the magnitude needed to alleviate the entire problem, many Delta levee experts believe that a comprehensive cost sharing arrangement amongst all benefiting parties needs to be established to equitably pay for needed improvements and maintenance. Others, however, do not wish to see such shared control over what they view as a local issue.

COMMENTS AND PERSPECTIVES OF PEER REVIEWERS

Reclamation District #548 in Lodi offered some recommendations, including: (a) long term cost sharing arrangements extending beyond the year 2000 should be implemented by the Legislature; (b) the Legislature should create an emergency fund; (c) State agencies should implement plans to preserve channel islands and enhance habitat on them. A concern was also raised that without State and/or federal assistance, levees protecting small islands will not be repaired as local residents cannot afford to do so on their own. The proposed emergency fund would be in place for this purpose.

The *California Central Valley Flood Control Association* cautioned that comparisons of 1982 Corps estimates of levee repair costs to costs associated with recent levee repair work might be misleading as the Corps' estimates included recreation and fish and wildlife enhancement in addition to basic structural rehabilitation.

The *State Reclamation Board* (Board) commented that it is responsible under agreements with the Corps for operation and maintenance of Project levees. There are currently about 17 miles of federal levees within the Delta which are in need of repair. The Board, the Corps, and affected reclamation districts will be cost-sharing efforts to repair these levees.

Reclamation District #2026, managing Webb Tract, commented that the briefing paper may give an overly pessimistic impression in that far less than half of the 550,000+acres in the Delta which are protected by levees are threatened by significant soft soil problems and subsidence.

The *East Bay Municipal Utility District* (EBMUD) emphasized that three of EBMUD's Mokelumne Aqueduct pipelines cross the Delta in areas which make them vulnerable to damage from levee failures caused by seismic activity or flooding.

The *Delta Protection Commission*'s Executive Director highlighted the apparent conflict between protecting the habitat value of the levees and the inspection, maintenance and rehabilitation problems associated with wildlife and vegetation.

The *Central Delta Water Agency* noted that significant funding provided by the State's Natural Disaster Assistance Act (over $26 million from 1980-1986) for emergency levee repair was critical to receiving $65 million in FEMA assistance.

DELTA LEVEE REPAIR AND MAINTENANCE ISSUES

INTRODUCTION

With respect to levee and channel maintenance in the Delta, there are inherent conflicts between retaining and restoring fish and wildlife habitat on levees and maintaining those levees for flood protection. Implementation of the Delta Flood Protection Acto of 1988 (SB-34) has been at the center of this debate.

Maintaining and developing habitat values on the levees is believed by many to threaten the levees' structural integrity or, at minimum, impair routine inspection, maintenance and repair. Still, despite disagreement among the players over emphasis and priorities, there is general agreement as to the benefits of protecting Delta islands and their important habitat values.

- LEVEE AND CHANNEL MAINTENANCE ISSUES

Dredging may result in temporary adverse water quality impacts, which can also affect aquatic resources in the impacted area. These concerns, particularly with respect to enforcement of the federal Endangered Species Act have limited dredging activities in the Delta to a 60 day period in the summer when fishery impacts are minimized. As long as the dredging window is so restricted, there is a risk that fill material from dredging will not be available to maintain and restore levees.

- LEVEE MAINTENANCE ACTIVITIES

Installation of revetments and riprap typically requires removal of vegetation which often results in conflicts with maintenance of both aquatic and terrestrial habitat. Many levee maintenance managers believe that extensive vegetation on the levees can present a hazard to flood protection capabilities. Fish and wildlife managers emphasize the importance of maintaining levee vegetation for habitat values.

- INTERAGENCY COORDINATION

There exists a Delta Levee and Habitat Advisory Committee within the Resources Agency that is working to (1) Streamline permits for levee work in the Delta; (2) Explore the utility of Habitat Conservation Plans; and (3) Provide guidance on Habitat Mitigation Plans.

- ISSUES AND IMPLEMENTATION OF THE SB-34 PROGRAM

SB-34 was enacted to facilitate and fund levee maintenance, with specific emphasis on New Hope Tract and eight key west Delta islands. SB-34 also focused on protecting and enhancing the fish, plant and wildlife resources of the Delta. Most significantly, SB-34 required that projects receiving funding from the Act would not result in a net long-term loss of riparian, fisheries or wildlife habitat. A DFG finding to that effect must be issued before funds are disbursed.

CONCLUSION

Though plagued by early conflicts between flood protection and habitat values, recent history suggests that the SB-34 program is becoming more effective. Continued focus on minimizing environmental impacts or, where possible, enhancing environmental values while developing innovative techniques to restore and maintain the structural integrity of the levees remains the key to successful programs.

SEISMIC STABILITY OF DELTA LEVEES

{*Draft* Report Published December 1993}

The islands in the Sacramento-San Joaquin Delta lie commonly 10 to 15 feet below sea level and are protected by levees against inundation from adjoining rivers and sloughs.

Most of the levees were built of non-select, uncompacted materials which were added piecemeal in lifts and/or berms. The resulting structures are embankments composed of mixtures of uncompacted sands, silts, clays, and organic soils. Similar structures commonly experience liquefaction and damage during moderate to strong earthquake shaking. Be that as it may, no record of a levee failure, or even significant damage to a levee as a result of earthquake shaking has been found. Nevertheless, there are several active faults located to the west of the Delta which are capable of delivering moderate to large shaking.

The consensus of several studies would seem to suggest that there would probably be levee damage and failure induced in the Delta by earthquake shaking within the next 30 years. The consequences of levee failure and island inundation depend upon the location of the inundated island and the flow conditions at the time of failure. Unlike many levee failures during winter floods, an earthquake-induced levee failure during low flow conditions (e.g. drought or summer months) could seriously disrupt water deliveries, as a consequence of water quality deterioration primarily through increased upstream salinity intrusion.

WATER SUPPLY

{*Draft* Report Published March 1994}

INTRODUCTION

There is general consensus today that the San Francisco Bay/Sacramento-San Joaquin Delta Estuary is not longer effectively functioning in its dual capacity as an important ecosystem and as the essential cog in the State's water supply network.

[Textual Note: It should also be noted and recognized that most of the data regarding California's estimated future water budget, upon which much of the analysis in this report is based, has been derived from the Department of Water Resource's draft California Water Plan Update, November, 1993, (draft Bulletin 160-93).]

- SURFACE WATER SUPPLIES AND THE DELTA

The Delta receives about 40 percent of the States's runoff. The Sacramento River Region has an average annual runoff of 23 MAF, and the San Joaquin River Region has an average runoff of 8 MAF.

- GROUND WATER SUPPLY

California's ground water storage is estimated at 850 MAF, in some 450 ground water basins. However, probably less than half of this total volume is usable because of prohibitive extraction costs and water quality considerations. An estimated 14 MAF of ground water is extracted to service agricultural, municipal, and industrial uses in an average water year. Current average annual net ground water use is about 8.5 MAF, including about 1.0 MAF of annual ground water overdraft. This represents nearly 20 percent of statewide applied water, In some areas, ground water accounts for as much as 90 percent of locally applied water

- DROUGHT

The effectiveness of California's Drought Water Bank is limited by the inability to transfer water through the Delta as a consequence of physical and regulatory pumping constraints.

- THE NEED AND DEMAND FOR WATER

California's populations is projected to increase to 49 million people by the year 2020 (from about 30 million in 1990). Even with extensive water conservation, it is estimated that annual net urban water demand will increase by 3.8 MAF from 6.7 MAF to 10.5 MAF by 2020.

Statewide irrigated agricultural acreage is expected to decline by nearly 400,000 acres, from the 1990 level of 9.2 million acres to a 2020 level of 8.8 million acres. Increases in agricultural water use efficiency, reductions in agricultural acreage, and shifts to less water intensive crops, are expected to decrease annual net agricultural water demand by about 2.3 MAF by 2020, from the current level of 26.8 MAF.

- WILL THERE BE ENOUGH WATER?

Continuing shortage conditions are projected even when a Delta solution is assumed. Without such a Delta "fix," many viable options that would otherwise be available to water managers to meet the estimated water deficit will be infeasible or otherwise unimplementable.

Currently, 4.6 MAF of Delta outflow is dedicated to fish and wildlife purpose under D-1485. In recent years, though, it has become increasingly apparent that these minimum flow criteria have not created the favorable conditions for fishery resources that had been expected and additional regulatory actions are presently under review.

[NOTE: On December 15, 1995, the State and Federal governments entered into an agreement whereby the amount of water required to serve in-Delta needs was established for a three-year period. This included approximately an additional 400,000 af of water in normal years and 1 MAF of additional water in dry/critical years. These flows are over and above the D-1485 criteria. It is expected that the Delta's ecosystem will benefit from this additional water.]

IMPORTANCE OF THE BAY-DELTA WATERSHED TO THE STATE'S WATER SUPPLY

■ DELTA DIVERSIONS

The Banks Plant is designed to pump a maximum of 10,300 cubic-feet-per-second (cfs) but is currently only permitted by the U.S. Army Corps of Engineers to pump on averages a maximum of 6,400 cfs. The CVP has a Delta pumping capacity of 4,600 cfs. In addition to these water facilities, there are 1,800 agricultural diversion within the Delta that, under riparian rights, divert a combined seasonal peak of 4,500 cfs to irrigate about 500,000 agricultural acres.

■ HYDROLOGY

Sacramento River Region: More than 40 major reservoirs lie within the Sacramento River Region. Exports from the Sacramento River basin are taken mainly from the Delta and are of paramount importance to the State's water supply. There are significant diversions of what would otherwise be Delta waters upstream of the Estuary, including San Frnacisco's Hetch-Hetchy system, East Bay Municipal Utiliity District's Mokelumne River diversions, and the Turlock & Modesto Irrigation Districts' Tuolumne River diversions.

San Joaquin River Region: About 47 percent of the San Joaquin Valley's 1990 level water supply comes from local surface sources, while imported surface supplies account for 29 percent. Ground water fulfills about 19 percent of the total 1990 level of average annual water supply for the region. The remaining 5 percent of water in the system is dedicated to in-stream flow. There are 57 major reservoirs in the San Joaquin Valley Region.

TRENDS IN WATER MANAGEMENT PROGRAMS AND DELTA TRANSFERS

The Delta influences the effectiveness of virtually all statewide water management activities and is thus a key factor in future supply scenarios.

■ MANAGEMENT ACTIONS AND OPTIONS

Water managers are (and have been) investigating a wide variety of management actions to supplement, improve, and more efficiently utilize existing water resources. However, recent actions taken to protect Delta fisheries have impacted the viability of many supply options formerly available to managers.

The following are some categories of actions that could help meet California's water supply needs through 2020.

Demand Management:
- ❖ Water Conservation
- ❖ Drought Land Fallowing and Water Bank Programs
- ❖ Drought Demand Management
- ❖ Land Retirement

Supply Augmentation:
- ❖ Water Reclamation

Solutions to Delta Water Management Problems would make more feasible --
- ❖ Increased conjunctive use and more efficient use of major ground water basins.
- ❖ Additional storage facilities south of the Delta.
- ❖ Increased water transfers across the Delta.

■ SOUTH OF THE DELTA STORAGE

Governor Wilson's water policy and the Legislature have identified storage south of the Delta as a critical means to increase future water supplies and reliability. However, current hydraulic and regulatory constraints in the Delta do not provide the major export systems with enough operational flexibility and certainty to make such storage projects feasible, and this feasibility will remain uncertain until Delta problems are resolved. Increased storage south of the Delta would allow for more reliable deliveries during low flow periods when Delta water need to remain instream to serve environmental needs and satisfy other regulatory mandates.

■ MOVING WATER SOUTH OF THE DELTA FOR STORAGE

Added reservoir storage south of the Delta is practically dependent on implementing corrective measures in the Delta to allow for requisite pumping operations when surplus flows are available.

■ NORTH OF THE DELTA STORAGE

North of the Delta storage options may become more feasible in the future, as Delta transfer problems are addressed.

FACTORS AFFECTING THE USE AND AVAILABILITY OF DELTA WATER SUPPLIES

■ HISTORICAL SETTING

Water exports directly from the Delta began in 1940, after completion of the Contra Costa Canal (a unit of the federal Central Valley Project). In 1951, water began being exported via the CVP's Tracy Pumping Plant into the Delta-Mendota Canal. The State Water Project's main California

Aqueduct began operation in 1967, extracting water from the Delta near Tracy as well. The North Bay Aqueduct began diverting water from the northwestern Delta in 1987.

In addition to direct in-Delta diversions, over 10 MAF of water that would otherwise flow to and through the Delta is withdrawn upstream by San Francisco's Hetch Hetchy Project, East Bay Municipal Utility Districts' Mokelumne Aqueduct, the Turlock Irrigation District, the Modesto Irrigation District, the Friant unit of the CVP, the Red Bluff Diversion dam and numerous other users.

■ DELTA FLOWS

Tidal Action: Because Delta channels are at sea level, they are affected by the tidal action of the Pacific Ocean and San Francisco Bay.

Fresh Water Inflow/Outflow: Fresh water flows into the Delta are typically of much lower volume than tidal inflows. Currently, minimum fresh water Delta outflow for most of the year is maintained by releases from SWP and CVP upstream storage reservoirs. A significant portion of this outflow is intended to establish a hydraulic barrier, utilizing the momentum and energy of these fresh water releases, to countervail tidal forces and prevent ocean water from intruding deeply into the Delta. Otherwise, Delta ecology and the quality of municipal and agricultural water supplies would be adversely affected.

■ REVERSE FLOW AND CARRIAGE WATER

When exports from the South Delta reach the upper range of interior channel capacity, sometimes water moves up the San Joaquin River in a "reverse flow" toward the pumps. There is a lively scientific debate over the significance of these reverse flows.

Currently, during operational periods when reverse flows occur, more water than is actually needed exclusively for export is released form project reservoirs to repel sea water intrusion, maintain in-Delta water quality standards, and satisfy export water quality standards. This incremental release of water from the reservoirs, in excess of the actual export need, is described as "carriage water."

Carriage water requirements in average and drought years are approximately 200,000 and 400,000 af respectively. As operational restrictions increase in the Delta, the volume of necessary carriage water may also increase. It should be noted that it is possible, when other regulatory requirements mandate increased reservoir releases to meet non-carriage needs, the carriage water component of those releases may actually decrease although total project flows have increased.

- NORTH AND SOUTH DELTA CHANNEL CAPACITIES

The limited capacities of channels in the North and South Delta contribute to problems of reverse flow, increased flooding, and poor water circulation.

- INSTITUTIONAL CONSTRAINTS

In addition to difficulties associated with Delta hydraulics, institutional constraints significantly influence water supply management in California. The institutional framework is very fragmented and must be responsive to various regulatory and legal requirements.

- REGULATORY CONSTRAINTS

Recent regulatory activities related to endangered species, promulgation of EPA Bay-Delta water quality standards, and Central Valley Project Improvement Act (CVPIA) mandates, illustrate the imperative of a Delta "fix" to halt decreasing water supply reliability and restore environmental health. Corrective actions in the Delta can reduce environmental impacts from the CVP, SWP and other sources and thus improve future water supply reliability. Many of these potential actions can not only reduce ecological impacts, but they help restore and protect the Estuary's biological resources. Perhaps the most powerful regulatory constraints are the State and federal Endangered Species Acts. The tate Water Resources Control Board, under both its Clean Water Act and water rights authority, plays a central role in determining some of the parameters of water management in the Delta.

INTRODUCED SPECIES

{*Draft* Report Published May 1994}

INTRODUCTION

Over the past decade, regulatory actions in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary have constrained water project operations to protect the native winter-run Chinook salmon, the native delta smelt, and other depleted fishery resources. Some water users have expressed concern over whether other factors impacting the Estuary have been given sufficient consideration as significant problems independent of the projects. One of the factors underlying this concern is the large number of introduced species in the Estuary in relation to the numbers of native species.

In 1991, seven of the ten most abundant species salvaged at the State Water Project fish screens were introduced species and the sport catch of introduced species during the 1980s in the Estuary exceeded the catch of native species.

The role of introduced species in the Estuary, and the possible limiting effects they may have on recovery of certain depleted species as well as overall restoration and protection of the Estuary ecosystem, is not well understood. Conditions in the Estuary are ever changing and new introduced organisms continue to be documented as surveys and field work are conducted in the Bay-Delta.

■ BACKGROUND

Introduced species can affect native fish, wildlife, and plants through a wide variety of mechanisms. These include: competition for space, competition for existing food resources, predation, disturbance, hybridization, pathways for and sources of disease, and physical alteration of the environment. Non-native plants can contribute to the incremental loss of habitats and biological diversity by affecting the ecological process of succession, productivity, stability, soil formation and erosion, mineral cycling, and hydrologic balance.

Introduced species have probably affected the abundance of native species in the Estuary. Only in a few cases, however, is data available to document introduced species as a significant cause of the decline of native species.

Monitoring during the last 25 years has been much more extensive than in previous periods. Department of Fish and Game (DFG) biologists have concluded that only the depletion of the native copepod (*Eurytemora affinis*) by introduced copepods, and, subsequently, the introduced Asian clam provides evidence of competition and predation by introduced species being the principal cause of a decline in the population of a native aquatic species. Native wildlife depletion attributable to predation and competition by introduced species is more direct and more widely evidenced.

Various views are held regarding the imapcts of introduced species. One prominent perspective holds that species such as the striped bass and largemouth bass were introduced into the system and have existed with native species since that time in the Estuary with little overall negative impacts. Although some, and perhaps extensive, alteration of native fishery resources undoubtedly occurred, benefits derived from these introduced species were considered sufficient at the time to justify their introduction. Non-native species should now be considered part of the Estuary's biological system. Many fisheries management experts believe restoration of the Estuary should include some non-native species, such as striped bass which provide important recreational opportunities for sport anglers and contribute to the economy of the State. They also believe this can be done without compromising the goals of restoring and protecting the Estuary.

A second perspective is that from the very first time that a non-native species was introduced into the system the biotic uniqueness and structure of the Estuary as a whole was destroyed. This alteration of the Estuary was such that non-native species were usually winners and native species losers. Advocates of this position tend to feel that management actions aimed at increasing the abundance of introduced species populations, such as striped bass, are in conflict with goals set for achieving recovery of native species.

A third view is held by experts who contend recovery efforts should focus on ecosystems from a more global perspective.

Efforts to prevent new species from becoming established in the Estuary have resulted in elaborate, expensive, and difficult to implement control programs directed by the Department of Fish and Game, Department of Boating and Waterways, and Department of Food and Agriculture.

■ INTRODUCED SPECIES

The Estuary is home to more than 150 introduced aquatic species of plants and animals including over 27 non-native fish species and over 100 species of marine invertebrates. The briefing paper discusses this collection in some detail. The more significant species are highlighted below.

Fish: Government agencies have intentionally introduced certain species to expand opportunities for angling and commercial fishing, to expand the forage base for predators, and to control pest populations. Other mechanisms for introduction include unauthorized transplants by individuals, and non-intentional introductions occurring incidental to commercial and sporting activities (i.e. discharge of ship ballast water, transport of organisms on the hulls of fishing boats, etc.).

Striped bass (Morone saxatilis) were introduced into the Estuary in the late 1800s. Striped bass were stocked by DFG from 1982 through 1992 in an effort to support and maintain the existing population. This practice was suspended by the DFG in response to concerns that the stocking of striped bass, which was a relatively small addition to the natural population, was adding predators to the system which could harm populations of the winter-run Chinook salmon. Evidence indicates striped bass decrease salmon abundance, but are not the principal factor in recent declines of salmon or delta smelt.

Largemouth bass (Micropterus salmoides), introduced in the late 1800s to enhance sport fishing, is one of several members of the sunfish family which, it is theorized, may have collectively out-competed the native Sacramento perch for habitat. While the prevailing judgement is that largemouth bass probably contributed to declines in various native fishes in the Delta, conclusive evidence has not yet been demonstrated.

Chameleon goby (Tridentigor trigonocephalus),was introduced sometime in the 1950s, and by 1990 it had become the most abundant species identified by DWR's southern Delta egg and larval sampling. Still, data as to the impacts of the chameleon goby on native species is inconclusive.

The *inland silversides* (Menidia beryllina) was introduced into Clear Lake and migrated to the Delta by the mid 1970s. Some experts have hypothesized that predation by silversides on eggs and larvae of delta smelt may be important in the decline of delta smelt.

Amphibians: *Bullfrogs* (*Rana catesbeiana*) introduced into California have been noted to prey upon and out compete native specie in areas where they coexist.

Reptiles: The impact of the few identified introduced reptiles is unknown.

Invertebrates: Changes in invertebrate populations have been more dramatic than those for fish in recent years. Several new species of zooplankton have dramatically changed species composition in brackish and freshwater portions of the Estuary.

The *asian clam* (Potomocorbula amurensis) was introduced in 1986. It occupies bottom space to the exclusion of other benthic species. The asian clam has a higher plankton filtration rate than most native invertebrates and has been implicated in the reduction in chlorophyll biomass and its production rate in Suisun Bay.

Wildlife: Several non-native wildlife species reside in the Estuary. A number of these species may be viewed as desirable; providing hunting and other recreational opportunities. Other non-native wildlife species which were introduced have expanded their numbers into the Estuary and have increased predation upon native wildlife populations, thus disrupting natural predator-prey relationships. Such introductions include the *norway rat*, *feral cats*, and the *red fox*.

Terrestrial Plants: There is a long history of concern about the impact of non-native plant species on wetland areas. The extent or cumulative effect of these species on native vegetation in the Estuary is not fully understood and more information is needed to better understand the complex, usually indirect, interactions of plants in natural environments; both for scientific understanding and to promote better vegetation management.

Aquatic Plants: Impacts on the Delta ecosystem from aquatic weeds include blocking flood control channels, increasing mosquito habitat, increasing siltation, changing water temperature, changing dissolved oxygen, obstructing boating recreation activities, and decreasing property values for properties adjacent to affected channels. Of particular concern is waterhyacinth.

PERSPECTIVES ON INTRODUCED SPECIES

The United States Congressional Office of Technology Assessment (OTA) submitted a report brief on "Harmful Non-indigenous Species in the United States" The brief states that harmful non-indigenous species have exacted a significant toll on U.S. natural areas, ranging from wholesale changes in ecosystems to more subtle ecological alterations. They have found that fundamental changes in structure and function of habitat were as much of a concern as species declines. That is, non-natives change the players, but can also change the rules of the game.

Lars Anderson of the Agricultural Research Service (ARS) identified three major needs: 1) increased systems-level approach to answering questions related to "fixing" the Delta; 2) efficient research coordination across federal, state, university, and private groups; and 3) current vegetation surveys coupled with the generation of GPS/GIS to establish a "baseline" so that future research can be planned and executed efficiently and effectively.

Don Stevens, a senior biologist of the DFG, commented that an appropriate goal is to restore a biologically diverse ecosystem which maximizes production of desirable recreational and economically important species while not jeopardizing the existence of natives. He stated that, for the most part, native fishes have endured despite numerous more or less indiscriminate intentional introductions that have dominated the Delta's fish fauna for more than a century. In addition, he commented that the present declines of both native and introduced species have occurred concurrently with major changes in water management.

Randy Brown, Chief of the Environmental Services Office in the Department of Water Resources commented that introduced species and other factors result in a constantly changing Estuary and one where few management measures can be successfully used to control these species. He believes federal and state agencies must do all in their power to limit future introductions, since it is essentially impossible to control species in the Estuary once they are introduced. He stated that one of the most important unresolved issues related to introduced species, especially fish, is their impacts on native species through competition for the same, often scarce, food resources.

Dr. Peter Moyle of the University of California Davis commented that even though species may overlap in diet and use of space, it does not mean they necessarily compete since the food source or space may not be in short supply. Still, because competition has not been demonstrated it does not mean that it does not exist.

Karen Wiese, of the California Native Plant Society (CNPS) commented that the CNPS views the introduction and proliferation of non-native plants in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary as a threat that disrupts and displaces native ecosystems resulting in a loss of biodiversity. She stated that the loss of biodiversity implies reduced functional values (or benefits) to the ecosystem and the region as a whole.

Ross O'Connell of the California Department of Food and Agriculture (CDFA) commented that the potential introduction and establishment of additional non-native species is not addressed in the briefing paper. He stated that hydrilla verticillata and the zebra mussel could be very devastating if they become established in the Delta.

Larry Thomas of the Department of Boating and Waterways (DBW) commented that there are at least three other non-native plant species (Egaria, Parrot feather, and Waterprimrose) in addition to waterhyacinth which have become a problem, or have the potential to become a problem.

CONCLUSION

The briefing paper acknowledges that the effects of introduced species and ecological complexities in the Estuary are far from definitive and more study is necessary to define the problem. The effect of introduced plants has been pronounced in the Estuary. Aggressive non-native plants have significantly altered the California landscape and the Bay-Delta Estuary is no exception. Introduced fish species have undoubtedly affected the abundance of native species in the Estuary, but the magnitude of such effects is very uncertain.

Most introduced species cannot be totally eliminated from the Estuary. Still, most resource managers agree that additional introductions are generally undesirable. Efforts to control non-native predatory mammals and invasive aquatic species should continue. A more aggressive effort to manage ballast water discharges, inclusion of invasive plant control in native plant restoration programs, and biological control of introduced invasive aquatic plants should also be undertaken. Future management actions will have to be undertaken recognizing that the full extent of impacts from introduced species on the Estuary is uncertain. It is important to consider how introduced species help define the Estuary's ecosystem and how they may impede recovery of specific native species.

RECREATION

{*Draft* Report Published December 1994}

INTRODUCTION

The Bay-Delta Oversight Council (BDOC) was not given the specific mission of promoting recreation in the Delta. However, some potential BDOC solution actions may exacerbate certain recreational impacts or conflict with recreation proposals by local, State, or Federal agencies. Therefore, consideration must be given to recreational impacts in order to implement fully effective BDOC solutions.

The Delta, because of its unique waterway system (featuring 1,100 miles of shoreline, 50,000 acres of water surface, and hundreds of islands), is one of the most popular destinations for outdoor recreation in California, particularly for boating and fishing enthusiasts. The Delta's high level of recreational use is also attributable to its close proximity to several large and expanding urban population centers.

- RECREATION IN THE DELTA

Present Recreation Uses: Recreation in the Delta is primarily water-dependent and many recreation areas are only accessible by boat, limiting their use by the general public.

Most public land in the Delta is managed primarily to protect and enhance wildlife resources. To the extent that such management conflicts with recreation, current and potential recreational opportunities may be limited.

Water-Based Recreation Activities: About half of all recreation in the Delta involves boating. Other popular forms of water dependent recreation include houseboating, sailing, boat fishing, jet skiing, anchoring, water skiing, canoeing, bank fishing, and windsurfing.

Land-Based Recreation Activities: The more popular land-based recreation activities include hunting, camping, picnicking, hiking, horseback riding, bicycling, bird watching, nature study, sightseeing and special events.

- ECONOMIC IMPACT OF RECREATION

Recreation and related support services are the third largest contributor, after agriculture and natural gas exploration, to the Delta economy.

- PAST TRENDS IN RECREATION

In general, basic recreation activities in the Delta have changed little over the last 20 years.

- FUTURE TRENDS IN RECREATION

Public recreation areas and facilities in the Delta needed to meet projected demand may not be provided. In addition, the lack of public funds will force government agencies to continue to rely on revenue-generating facilities and services at existing and any proposed recreation areas.

- FUTURE RECREATION OPPORTUNITIES

Public Recreation Opportunities: Existing public recreation areas and facilities in the Delta are insufficient to meet current and future recreation demand. Considering the lack of funds available to public agencies, the prospect of providing adequate additional public recreation opportunities in the immediate future seems remote.

Private Recreation Opportunities: Delta recreation is heavily dependent upon private marinas with boat launching ramps, campgrounds, and related support facilities. In recent years, several proposals for new marinas have been submitted to government agencies for consideration, but few have actually been constructed due to funding, permitting, or economic reasons.

- CURRENT RECREATION PLANNING EFFORTS

State and local Recreation planning in the Delta has been described as haphazard and uncoordinated. Local recreation planning, and all other land-use planning, is typically a county responsibility. Each of the five Delta counties has adopted a General Plan; however, there is little planning coordination among the counties, and each county addresses Delta recreation issues differently. Recreation planning, at the state and federal level, as well as at the local level, is not successfully coordinated.

Local Recreation Planning: Although each of the Delta counties has adopted a General Plan, including an open space and/or recreation element, each county's approach to planning varies. In addition to the counties, many cities and communities in or near the Delta have also adopted General Plans with open-space and/or recreation elements.

The Delta Protection Commission is updating their recreation and access study for the Delta. As a result of this study, policies adopted by the Commission will become part of a new Delta Regional Plan, which would then be incorporated by the five Delta counties general plans to guide future recreational and public access planning and development.

State Recreation Planning: Many state agencies have prepared major reports on Delta recreation planning. These reports, developed independently by various agencies, occasionally resulted in conflicting proposals.

- CURRENT REGULATIONS

There are currently no state or regional provisions to resolve conflicts or inconsistencies between local, state, or regional plans. Consequently, there are no clear, consolidated Delta-wide policies to regulate the placement of recreation facilities or control recreation activities in the Delta.

■ MAJOR RECREATION ISSUES

Impact of Recreation on Levees

Levee Inspection Efforts. Reports and studies often cite marinas located adjacent to levees as impediments to inspection efforts.

Flood Fighting Efforts. During major floods, boats and other floating debris from marinas may break free and block bridge openings, exacerbating flood danger. Marina structures and facilities are also cited as potential impediments to fighting floods.

Levee Maintenance Efforts and Costs. The perception that levees near marinas are more time-consuming and expensive to maintain may arise from the concentrated use of levees near marinas. Recreationists camping on Delta levees, berms, and revegetation sites has also been cited as a cause of increased maintenance costs.

Erosion Due to Boat Wake. Levee erosion caused by the wake of passing powerboats is one of recreation's biggest impacts on the Delta.

Disturbance to Levees and Berms. Recreationists, especially anglers who drive, walk, or camp on unprotected levees and berms, can disturb the soil and accelerate slope erosion.

Impact of Recreation on Delta Waterways

Reduced Public Access to Waterways. Development of recreation facilities such as marinas, yacht clubs, and duck clubs can restrict the public's access to Delta waterways. Besides structures on the shore, structures in Delta waterways can also impede public use. In 1981, the US Army Corps of Engineers identified approximately 200 known illegal structures in the water, including private slalom courses, ski jumps, and docks.

Boating Safety. For many years, some Delta user groups have expressed concern over the seemingly high number of boating accidents in the Delta. As part of a Department of Boating and Waterway's 1985 study on boating safety in the Delta the following actions were recommended: 1) state and local agencies should do more to emphasize boating safety education and enforcement; 2) all buoys, waterway markers, information signs, and control zones should be uniform; 3) state and local agencies should do more to inform the boating public of safety problems unique to the Delta, such as merging channels and blind intersections; and, 4) require every person who is convicted of a boating violation to pay a fine or complete a boating safety education course.

Conflicting Water Activities. Recreational use of Delta waterways is essentially unregulated. As a consequence, there are many conflicts between various recreational uses on Delta waterways.

Impact of Recreation on Public and Private Lands

Impacts of recreation on public and private lands include: encroachment on public lands; trespassing on private property; vandalism; fires; off-road vehicles; increased maintenance costs; and, litter and trash.

Impact of Recreation on Fish, Wildlife, and Riparian Habitat

The Delta's enduring attraction for recreation purposes is closely linked to protection and management of both fish and wildlife. Riparian habitat plays an important role in this effort. Not only does it sustain the fish and wildlife that are an essential part of the Delta recreation experience, it also provides an aesthetic attraction.

Impact on Fish: Facilities, boat maintenance, and waste dumping contribute to water pollution and water quality degradation. Recreational fish harvest sometimes includes illegal take and is a factor in fish management decisions

Impact on Wildlife: Some Delta recreation activities, such as hunting, bird watching, and nature studies, are directly dependent on the quantity and quality of wildlife. Human noise and activity and litter are troublesome for wildlife. Hunting in the Delta is carefully regulated to prevent serious threats to overall population survival. Illegal hunting has not been determined to be a serious problem.

Impact on Riparian Habitat

Riparian habitat confers on the Delta its characteristic aesthetic quality while also sustaining fish and wildlife. In addition, it often provides shelter to boaters, campers and other recreationists.

The Delta Recreation Master Plan (1976) identified some adverse environmental effects of recreation on Delta habitats: 1) trampling and destruction of vegetation; 2) occasional vandalism; 3) litter accumulations which can injure fish and wildlife; 4) occasional uncontrolled fires (including peat) caused by careless smokers, off road vehicles, campfires and arsonists; 5) localized and increased traffic into natural areas; and, 6) air pollution. Boat-wake is also a problem.

- INTERRELATIONSHIPS

Interrelationship Between Recreation and Agriculture.

Recreation and agriculture compete for the Delta's limited supply of land. The interrelationship between recreation and agriculture can be mutually beneficial.

Interrelationship Between Recreation and Fish and Wildlife.

Duck and pheasant clubs, managed to attract game birds, also provide food and cover for non-game birds and other wildlife. Bird watching and nature study are non-intrusive activities which also increase the public awareness for protection and enhancement of habitat and wildlife values.

Interrelationship Between Recreation and Riparian Habitat.

Riparian habitat is not only essential for wildlife, it also provides natural shade for boaters and campers.

Interrelationship Between Recreation and the Local Economy.

The relationship between local residents and recreationists can be mutually beneficial. Goods and services provided by local merchants are an essential element of a good recreational experience.

Interrelationship Between Recreation and Private Property Rights.

The relationship between recreationists and property owners is often one marked by resentment and frustration.

Interrelationship Between Recreation and Flood Control.

The presence of large numbers of recreationists, and associated recreational facilities increases potential flood losses, complicates evacuation procedures, and adds to the costs of levee maintenance.

Interrelationship Between Public and Private Recreation.

There are few public waterways in California where there is so much recreation and so few public facilities. In the Delta, the private sector, not the government, is the primary supplier of publicly accessible recreation facilities and services.

Interrelationship Between Recreation and Other Delta Resources.

Most proposals to increase recreational activity have a direct or indirect negative impact on biological or agricultural resources and may impact flood protection. Conversely, efforts to improve some other Delta resources could have a negative impact on recreation.